Numbers and types of arthropods overwintering on common mullein, *Verbascum thapsus* L. (Scrophulariaceae), in a central Washington fruit-growing region

DAVID R. HORTON and TAMERA M. LEWIS

USDA-ARS, 5230 KONNOWAC PASS Rd., WAPATO, WA, UNITED STATES 98951

ABSTRACT

Densities and types of arthropods overwintering on common mullein, *Verbascum thapsus* L., in a fruit-growing region of Central Washington were determined. Over 45,000 arthropods were collected from 55 plants (5 plants from each of 11 sites), dominated numerically by Acari and Thysanoptera. Insects representing 8 orders and 29 families were identified, distributed both in the basal leaf rosettes and in the stalk material of the plants. One specialist insect herbivore of mullein, the mullein thrips, *Haplothrips verbasci* (Osborn), was abundant at all sites. Several pest and predatory taxa that commonly occur in orchards were also collected, suggesting that mullein may be a source of overwintered pests or predators moving into orchards in early spring. Pest taxa included primarily western flower thrips (*Frankliniella occidentalis* (Pergande)), *Lygus* spp., and tetranychid spider mites. Common predators included phytoseiid mites and minute pirate bugs (*Orius tristicolor* (White)). Sites that were geographically close to one another were not more similar (in taxonomic composition of overwintering arthropods) than more distantly separated sites.

Key words: common mullein, overwintering, orchard pests, predatory arthropods, mullein thrips, western flower thrips, *Orius tristicolor*, mites

INTRODUCTION

Common mullein, *Verbascum thapsus* L. (Scrophulariaceae), is a biennial herb native to Eurasia (Munz 1959) but now common throughout North America. The species occurs in open waste areas, along fence lines, in overgrazed pastures, and along river bottoms, often found growing in large single-species stands. Common mullein has a biennial life cycle, germinating from seed often near clumps of the dead parental plants. In the first year, the plant develops as a rosette of soft, bluish-gray leaves which are densely covered with silky hairs. The following year, a stout, leafy stalk is sent up from the center of the rosette, often reaching a height of more than 2 m in mid-summer. At the top of the stalk is a spike having 100-200 yellow flowers which are in bloom several at a time for much of the summer.

There is a great deal of interest in managing or conserving non-agricultural habitats adjacent to agricultural habitats to enhance biological control or to reduce infestation of crops by pest species (Pickett and Bugg 1998; Ekbom *et al.* 2000). In Pacific Northwest fruit growing regions, common mullein often is abundant on the perimeter of pome and stonefruit orchards. The plant is known to harbor important pests of tree fruits during the growing season (Thistlewood et al. 1990; Krupke et al. 2001), but it also is an important source of certain predators (e.g., *Campylomma verbasci* (Meyer), the mullein bug) that may provide biological control of aphids and mites during the growing season. Less information is available concerning use of mullein by pests and predators as an overwintering habitat (McAtee 1924). It is important to understand late winter and early spring population dynamics of pests and predators in pear and apple orchards, as that time of year is often crucial for pest control. Thus, we need also to understand the overwintering biology of arthropods both inside and outside of the orchard, including a determination of where pests and predators overwinter

(Horton and Lewis 2000; Horton *et al.* 2002).

McAtee (1924), in Maryland, conducted a cursory survey of the insects associating with common mullein, and found that the dense basal rosette of leaves provided overwintering habitat for several taxa of arthropods, including both pest and predatory insects. Thus, in addition to being a source of pest and beneficial arthropods during the summer and fall growing season, common mullein may also be a source of overwintered arthropods moving into Central Washington orchards in late winter and early spring. Objectives of the present study were to determine types and densities of arthropods overwintering on common mullein in a fruit-growing region of Central Washington. The study was designed to provide a more thorough look at the arthropod communities in mullein than provided by McAtee (1924), and to provide data for a western US population of mullein. We also compared types and numbers of arthropods overwintering in the basal rosette of leaves to numbers and types occurring in the leaves, dried flowers, and seed capsules of the stalk. Lastly, we looked for geographic patterns in the taxonomic composition of arthropod communities overwintering in mullein, testing the hypothesis that arthropod communities would be more similar between sites that occur geographically near one another than between sites that were more widely separated.

MATERIALS AND METHODS

The study was done in and adjacent to Yakima, Washington, USA. Eleven sites, each having stands of fully mature common mullein, were selected in November 2000 for sampling. Plants that were sampled had bloomed the previous summer and were composed of dead leaves and seed-laden stalks at the time of collection. All of the sites were along roadsides that occurred immediately adjacent to orchard habitat or within 1 km of orchard habitat. Straight-line distances between sites ranged between 0.5 to 46.4 km. In December 2000 and January 2001, we collected five fully mature plants (1.5 to 1.8 m tall) from each site by cutting the plants just beneath the soil surface. Plants were placed in large plastic bags for transport to the laboratory. Bags and plants were placed in a large walk-in cooler (2 °C) until the arthropods were extracted. To extract the arthropods, the plant material was distributed among 25 Berlese-Tullgren funnels (Southwood 1980), keeping stalks and leaf rosettes separate. We used 40 watt light bulbs to force the arthropods into 75% ethanol.

Arthropods were then separated from the plant detritus by first slowly pouring the alcohol through very fine (0.2 x 0.2 mm) organdy mesh. The mesh appeared to capture all but the very smallest mites (mostly immature Tydeidae and Tenuipalpidae). These specimens were discarded without being identified, thus summaries provided below for Acari underestimate total numbers of certain small-bodied taxa. The arthropods remaining on the mesh were removed from the mesh and plant detritus with forceps, insect pins, or small paint brushes, and transferred to fresh 75% ethanol for later counting and identification.

Insects other than Lepidoptera (all of which were in the caterpillar stage) and parasitic Hymenoptera were identified at least to family. Known important predators and pests in orchards were identified to species. Most samples contained very large numbers of Thysanoptera, and it was not feasible to identify each specimen. A subsample of 50 thrips was removed from each sample for identification to genus beneath a dissection microscope, using the key of Mound and Kibby (1998). Immature thrips were not classified. Results for the subsample were then extrapolated back to the full sample to provide estimates of total numbers of thrips for each genus. Representative examples of each genus were sent to an expert in thrips identification (Steve Nakahara; Beltsville, MD) to confirm our identifications.

Mites were very abundant in the leaf rosettes and much less abundant in the stalk material, thus we limited acarine identifications to those mites inhabiting the leaf rosettes. The identifications were confined to six of the 11 sites. We first separated Gamasida from the total sample, for later examination. From the remaining sample, a subsample of approximately 50 to 500 mites (depending upon total numbers in the sample) were mounted in Hoyer's solution on microscope slides (Krantz 1978). The mites were then identified to genus (*Tetranychus* spp. only) or to family under a compound microscope using keys in Krantz (1978). Counts for *Tetranychus* spp. were then extrapolated back to the total sample to obtain estimates of absolute densities for *Tetranychus* spp. From the Gamasida whole sample, subsamples of 25 to 85 mites were then taken for those sites having large numbers of gamasid mites (>90 mites). The mites were mounted on slides in Hoyer's solution and identified to family (all but Phytoseiidae) or to species (Phytoseiidae). Species identifications for the Phytoseiidae were made using keys in Schuster and Pritchard (1963) and Chant *et al.* (1974). We then extrapolated results for the subsample back to the full Gamasida sample to provide estimates of absolute numbers for phytoseiid species.

Straight-line distances between sites were obtained using a Vista global positioning unit (Garmin; Olate, KS). We tested whether sites that were geographically near one another were more similar than those more distantly separated by calculating taxonomic (family-level) similarity between all possible site pairs, using the following formula:

$$\text{Relative absolute distance} = \sum_i \text{Absolute value}\ [(x_{ij}/\sum_i x_{ij}) - (x_{ik}/\sum_i x_{ik})],$$

where j and k are two sites, x_{ij} is the abundance of the i^{th} insect family at site j, and x_{ik} is abundance of the i^{th} insect family at site k (Ludwig and Reynolds 1988). The analysis was limited to families of Insecta. The index varies between 0 and 2, with 0 indicating maximum similarity and 2 indicating complete dissimilarity between the two sites.

RESULTS

A total of 46,712 arthropods was counted from the 11 sites, of which 44.7% were collected from the leaf rosettes and the remaining 55.3% were collected from the stalk material. The samples were dominated numerically by the Thysanoptera and Acari (Table 1), accounting for over 90% of the arthropods from both leaf and stalk material. For the Insecta, 29 families in 8 orders were identified, with species of Thysanoptera, Coleoptera, and Heteroptera being the most abundant. There was considerable site-to-site variation in counts (Table 1, Range) for virtually all common taxa.

Mites were very abundant in the leaf rosettes (exceeding 500 per 5-plant sample) and much less abundant in the stalk material (Table 1). Specimens from leaf rosettes at six of the 11 sites were identified, and were found to include large numbers of Gamasida and Actinedida (Table 2). Gamasida were composed primarily of Phytoseiidae, including some important predatory species (*Amblyseius* spp.; *Typhlodromus caudiglans* Schuster; western predatory mite, *Galendromus occidentalis* (Nesbitt)). Spider mites (Tetranychidae) were relatively uncommon (Table 2), and included primarily *Tetranychus* spp. (47 of 64 tetranychids in subsamples).

Thysanoptera included two families, Thripidae and Phlaeothripidae (Table 1), the latter apparently being represented by a single species, *Haplothrips verbasci* (Osborn), the mullein thrips. This species was very abundant in both stalks and leaf rosettes, reaching densities of over 800 adults per stalk at one site. Thripidae included species of *Thrips* (apparently mostly *Thrips tabaci* Lindeman but including *T. fallaciosus* Nakahara), *Caliothrips*, and *Frankliniella* (apparently all western flower thrips, *F. occidentalis* (Pergande)).

Homoptera were composed primarily of aphids and psyllids (Table 1), including pear psylla, *Cacopsylla pyricola* (Foerster), a pest of pears. Heteroptera were dominated numerically by Anthocoridae and Miridae (Table 1). The 75 Tingidae that were collected all occurred in the leaf rosettes at a single site. Anthocoridae were almost exclusively minute pirate bug, *Orius tristicolor* (White) (164 total specimens), but included also five specimens of *Xylocoris umbrinus* Van Duzee. Overwintering Coleoptera were dominated numerically

Table 1

Mean (averaged over 11 sites) numbers of arthropods per 5 mullein plants in leaf rosettes and stalk material. Numbers in parentheses indicate percentage of total arthropods composed of that taxon [(tr) indicates less than 0.1%]. Range shows minima and maxima across the 11 sites. Family means may not sum to order means due to presence of unidentified arthropods in that order (particularly true for Thysanoptera, for which immatures were not identified).

	Leaf rosettes		Stalks	
	Mean numbers per 5 plants (%)	Range (per 5 plants)	Mean numbers per 5 plants (%)	Range (per 5 plants)
Acari	534.2 (28.1)	123-1455	34.0 (1.4)	3-167
Thysanoptera	1266.9 (66.7)	30-3936	2263.5 (96.5)	210-5516
Thripidae	515.6	0-2362	590.4	49-1655
Phlaeothripidae	710.6	25-1652	1467.5	64-4174
Homoptera	8.0 (0.4)	1-29	4.5 (0.2)	0-22
Aphididae	3.3	0-14	0.6	0-3
Cercopidae	0.1	0-1	0.0	0
Cicadellidae	0.3	0-1	0.0	0
Psyllidae	4.3	0-14	3.8	0-8
Heteroptera	30.5 (1.6)	4-87	8.9 (0.4)	0-32
Anthocoridae	7.5	0-22	7.7	0-30
Berytidae	0.1	0-1	0.0	0
Lygaeidae	1.6	0-16	0.0	0
Miridae	10.6	0-64	0.8	0-6
Nabidae	0.1	0-1	0.0	0
Pentatomidae	0.6	0-2	0.0	0
Reduviidae	0.1	0-1	0.0	0
Rhopalidae	2.3	0-12	0.1	0-1
Tingidae	6.8	0-75	0.0	0
Coleoptera	35.6 (1.9)	1-169	33.5 (1.4)	6-98
Anthicidae	0.0	0	0.1	0-1
Carabidae	0.2	0-1	0.0	0
Coccinellidae	0.5	0-1	0.0	0
Corylophidae	5.7	0-37	0.6	0-6
Curculionidae	27.5	1-130	32.5	6-98
Dermestidae	0.0	0	0.1	0-1
Staphylinidae	0.8	0-3	0.0	0
Neuroptera	0.5 (tr)	0-2	0.1 (tr)	0-1
Hemerobiidae	0.5	0-2	0.1	0-1
Lepidoptera	3.9 (0.2)	0-17	0.3 (tr)	0-2
Diptera	2.7 (0.1)	0-16	0.4 (tr)	0-2
Cecidomyiidae	1.5	0-11	0.2	0-2
Chironomidae	0.2	0-2	0.1	0-1
Mycetophilidae	0.1	0-1	0.0	0
Syrphidae	0.1	0-1	0.0	0
Hymenoptera	10.2 (0.5)	0-73	0.5 (tr)	0-2
Parasitoids	3.5	0-7	0.5	0-2
Formicidae	6.5	0-69	0.0	0
Vespidae	0.1	0-1	0.0	0
Araneae	7.4 (0.4)	0-21	0.8 (tr)	0-3
Opiliones	0.1 (tr)	0-1	0.0 (tr)	0
Chilopoda	0.2 (tr)	0-1	0.0 (tr)	0
Isopoda	0.1 (tr)	0-1	0.0 (tr)	0

Table 2
Taxonomic composition of mite subsamples (Oribatida, Acaridida, Actinedida) and absolute numbers of Gamasida in mullein leaf rosettes at each of 6 sites.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Oribatida	49	1	5	27	0	1
Acaridida	2	35	5	7	6	1
Actinedida	76	121	55	551	57	237
Anystidae	53	37	15	3	7	7
Bdellidae	2	14	0	0	0	0
Camerobiidae	10	4	4	0	4	17
Cunaxidae	0	0	1	7	0	0
Raphignathidae	3	21	11	0	1	0
Smarididae	2	11	0	0	0	0
Tarsonemidae	0	0	0	128	0	0
Tenuipalpidae	3	0	0	0	1	0
Tetranychidae	2	31	13	4	9	5
Tydeidae	1	3	11	409	1	208
Unidentified	0	0	0	0	34	0
Counted but not classified	0	235	90	841	92	364
Gamasida	238	94	58	29	52	379
Ameroseiidae	0*	0*	0	4	0	0*
Ascidae	1*	1*	38	2	0	0*
Laelapidae	0*	8*	7	0	0	0*
Phytoseiidae	83*	17*	13	23	51	81*
Unidentified	1*	1*	0	0	1	3*

* Results for a subsample of mites taken from the Gamasida total.

by an unidentified weevil that appears to be associated with the flowering and seeding mullein stalk also during the growing season. For the remaining taxa, spiders and ants were fairly abundant (both exceeding five specimens per 5-plant sample) in the leaf rosettes. Over 90% of the ants were collected at a single site.

Known tree fruit pests overwintering in mullein included pear psylla, spider mites, western flower thrips, *Lygus hesperus* Knight, and *Lygus elisus* Van Duzee (Table 3). Western flower thrips was especially abundant in the stalks, where densities reached 1000 thrips per 5- plant sample. *Lygus* spp. had a density of over 10 bugs per 5-plant sample overwintering in the leaf rosettes (Table 3). Beneficial arthropods known to occur in orchards and found overwintering in mullein included primarily phytoseiid mites and minute pirate bugs (Table 3), with much lower numbers of a few other species. Phytoseiidae included species of *Typhlodromus*, *G. occidentalis*, and unidentified *Amblyseius*. Minute pirate bugs were common, having a density of almost 15 bugs per 5-plant sample.

Taxonomic similarity (based upon insect families) between sites showed no relationship with distance between sites (Fig.1).

DISCUSSION

A large and diverse community of arthropods used both the leaf rosettes and stalks of common mullein as overwintering habitat. The communities were dominated numerically by Thysanoptera (leaves and stalks) and Acari (leaves), but other taxa including Heteroptera and Coleoptera were also relatively common. At certain sites, insects and mites overwintering in mullein easily exceeded a density of 1000 arthropods per plant, numbers considerably larger

Table 3

Mean densities (averaged over 11 or 6 [Acari] sites) of arthropods found overwintering in mullein that are also known pest or natural enemy inhabitants of orchards. Densities expressed as numbers per 5 mullein plants. Mites not identified for stalk samples.

		Leaf rosettes	Stalks
ORCHARD PESTS			
Acari	Tetranychidae	25.8	--
	Tetranychus (*urticae* group[1])	19.0	--
Thysanoptera	*Frankliniella occidentalis*[2]	280.0	733.4
Homoptera	*Cacopsylla pyricola*	3.5	3.6
Heteroptera	*Lygus* spp.	10.5	0.6
ORCHARD BENEFICIALS			
Acari	Phytoseiidae	124.0	--
	Galendromus occidentalis[3]	106.5	--
	Typhlodromus spp.[3]	11.3	--
	Amblyseius spp.[3]	6.2	--
Heteroptera	*Orius tristicolor*	7.2	7.7
	Deraeocoris brevis (Uhler)	0.1	0.2
	Geocoris spp.	0.6	0.0
Coleoptera	*Stethorus picipes* Casey	0.2	0.0

[1] Mean density estimated by extrapolating from subsamples (Table 2); spider mites were identified using keys in Baker and Tuttle 1994.

[2] Mean density estimated by extrapolating from subsamples.

[3] Mean density estimated by extrapolating from subsamples of Gamasida (Table 2).

than those reported by McAtee (1924) in Maryland (who appears to have ignored Acari and Thysanoptera in his brief study). It is of interest that a plant native to Eurasia would host such substantial numbers of phytophagous arthropods in North America. However, several of the most common species that we collected are cosmopolitan or Holarctic in distribution, including western flower thrips and mullein thrips, and it is likely that these species have geographic ranges in Europe and Asia that overlap the native range of common mullein. Indeed, the mullein thrips is known to specialize on species of *Verbascum* in Europe and North America (Bailey 1939). Bailey records this thrips as overwintering both in the leaf rosette and in the seed capsules or stalk material of *V. thapsus*, as shown also here.

The western flower thrips was very abundant overwintering in mullein (Table 3), suggesting that this plant may be an important source of flower thrips moving into orchards during early spring. Western flower thrips is a major source of early season damage on nectarines and certain apple varieties in the Pacific Northwest (Madsen and Jack 1966; Bradley and Mayer 1994; Pearsall and Myers 2000). Pearsall and Myers (2000, 2001) concluded that location of nectarine orchards in relation to wild habitats strongly affected early-season densities of thrips in orchards, with those orchards adjacent to other orchards (rather than adjacent to non-orchard habitats) having the lowest spring densities of thrips. These authors suggested that certain herbaceous and shrubby plant species in native habitats of the Pacific Northwest are a source of flower thrips that colonize nectarine orchards. Pearsall and Myers (2000) did not include common mullein in their list of important plant species, but results reported here indicate that common mullein should also be considered to be an important source of western flower thrips in tree fruit growing regions of the Pacific Northwest.

Other potential pests of tree fruits, including pear psylla, *Lygus* spp., and spider mites, were present in mullein but at considerably lower densities than flower thrips. Pear psylla is known to overwinter in a variety of locations outside of the pear orchard (Kaloostian 1970). *Lygus* spp. are sporadic pests in pear, apple, and stone fruit crops (Beers *et al.* 1993). Common mullein has been reported to be a host plant of *Lygus lineolaris* (Palisot de Beauvois) in eastern North America (Young 1986), but it is not clear whether the two species recovered in the present study (*L. hesperus* and *L. elisus*) use mullein as more than overwintering habitat. McAtee (1924) recorded that *Lygus* sp. overwintered on common mullein leaf rosettes in Maryland. Spider mites are often abundant on broad-leaf plants within and adjacent to orchards, and these plants appear to be sources of pest mites moving into fruit trees during the summer (Flexner *et al.* 1991; Alston 1994; Coli *et al.* 1994). Our results indicate that common mullein growing near orchards in the Pacific Northwest may be a source of overwintered spider mites that could eventually disperse into fruit trees.

Several important predator species also overwintered on common mullein, including the highly abundant *O. tristicolor* and predatory mites. *Orius tristicolor* is an important predator of thrips, mites, and other small soft-bodied prey (Askari and Stern 1972; Salas-Aguilar and Ehler 1977). This and other species of *Orius* are known sources of biological control in orchards (Westigard *et al.* 1968; Niemczyk 1978; McCaffrey and Horsburgh 1986), and our results suggest that mullein could be a source of early spring populations of *O. tristicolor* in orchards. McAtee (1924) collected *Orius insidiosus* (Say) overwintering on common mullein in Maryland.

Predatory mites were abundant in mullein, and included three genera (*Galendromus*, *Typhlodromus*, *Amblyseius*) that are common in apple and pear orchards of North America (McGroarty and Croft 1978; Croft *et al.* 1990; Horton *et al.* 2002), where they provide biological control of pest mites (Hoyt 1969). As with spider mites in orchards, predatory mites may colonize fruit trees from herbaceous or shrubby vegetation within or adjacent to orchards (McGroarty and Croft 1978; Johnson and Croft 1981; Alston 1994). Thus, the present study suggests that common mullein could act as a fairly important source of beneficial mites that provide biological control of pest mites in Pacific Northwest orchards.

There was substantial variation among sites in densities of arthropods overwintering on mullein (range: 272 arthropods per plant to 1986 arthropods per plant). Any of several factors could have contributed to this variation, including host quality, types and amounts of insecticides used in nearby orchards (e.g., Thistlewood *et al.* 1990), and local environmental or microenvironmental conditions. We hypothesized at the beginning of this study that sites close to one another geographically would tend to have taxonomically similar communities compared to sites geographically separated. There was no support for this hypothesis (Fig. 1), possibly due to the fact that two taxa (Thripidae and Phlaeothripidae) were almost invariably the most numerically dominant taxa at all sites, and comprised more than 80% of all arthropods collected.

CONCLUSIONS

Both the leaf rosettes and stalks of common mullein provided overwintering habitat to a large and taxonomically diverse collection of phytophagous and predatory arthropods. Because this plant species commonly occurs in disturbed habitats adjacent to tree fruit orchards in the Pacific Northwest, it may be an important source of both pest and beneficial arthropods colonizing orchards. It is not possible to speculate on whether growers benefit from having large stands of mullein growing near their orchards, as the potential benefits must be judged relative to the possible harm caused by pests which overwinter on the plant or use it as a host during summer. The net effect in an orchard of being adjacent to stands of mullein would depend, at a minimum, on the numbers of pest and beneficial arthropods overwintering in the stand (which appears to be highly variable among stands), as well as each species'

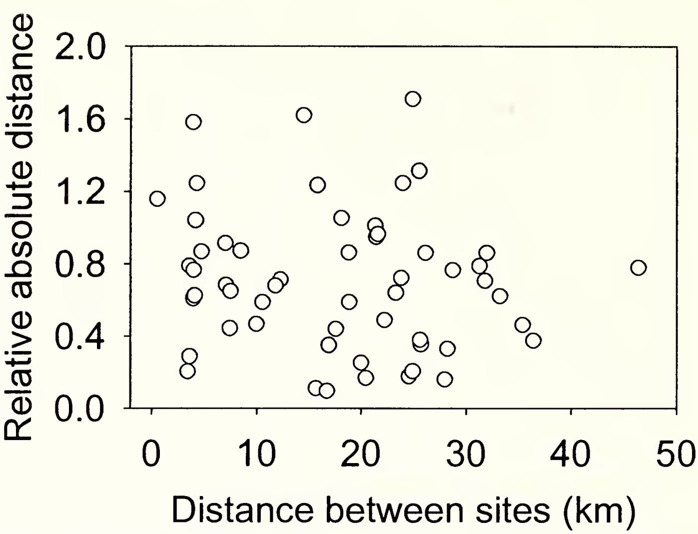

Figure 1. Scatter plot showing relationship of relative absolute distance (i.e., taxonomic similarity) and geographic distance for all possible pairings of sites. Smaller values of relative absolute distance indicate increasing taxonomic similarity between sites. Analysis limited to Insecta at family level.

tendency to disperse into orchards. Until we better understand factors affecting overwintering densities of specific pest and beneficial arthropods, and their post-overwintering movements, it is impossible to predict whether mullein is beneficial or detrimental for growers.

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